Thin Film
Room 2020 - Session TF1-ThA

Field Emission

Moderator: B. Holloway, Luna Nanoworks

2:00pm **TF1-ThA1 Field Emitter Arrays: Issues and Opportunities***, J. Shaw,* Naval Research Laboratory **INVITED**

An electron source technology compatible with micro-fabricated structures would enable many new devices ranging from x-ray sources to a new generation of high frequency vacuum electron devices. One well-known candidate source is the field emitter array. Field emission allows electrons to be removed from solids without first raising their energy (eg by heat or radiation), making them very convenient to use. The non-linear I-V characteristic allows row-column addressing. Local emission current densities over 10@super 8@ A/cm@super 2@ are possible, limited by space charge. Field emitter arrays, multiple field emission structures together with local electrodes used to produce the extraction field, can be fabricated using a number of standard and exotic patterning methods. Individual cells in an array typically have dimensions on the order of 1 micron. Transit through the high field region takes less than 1 pS, potentially allowing THz emission modulation. Average current densities over 10@super 3@ A/cm@super 2@ and total currents over 100 mA have been demonstrated. However, producing these outstanding results is not easy. One might assume that N field emitters in parallel might produce N times the current that can be produced by a single tip. But variations among emitters typically allow only a small fraction of the emission sites to produce current, and the fraction tends to decline with the number of emission sites. The total current is typically no more than 10@super 3@ times the maximum current from a single emitter, even when 10@super 5@ or 10@super 6@ emitters are present. The poor uniformity is not surprising, given that the field emission current is sensitive to both the shape of the emitter and the density and energy of electrons at the surface. I will discuss some strategies for improving the total emission current.

2:40pm **TF1-ThA3 Field Emission Performance in Various Vacuum Conditions and Multistage Field Enhancement Effect of Tungsten Oxide Nanowires***, **R. Seelaboyina**, J. Huang,* Florida International University*; D. Kang, J. Park,* Samsung Advanced Institute of Technology, Korea*; W.B. Choi,* Florida International University

We report on the field emission properties of tungsten oxide nanowires grown on a tungsten tip and its emission performance in various vacuum conditions. Tungsten oxide (W@sub 18@O@sub 49@) nanowires were grown by thermal chemical vapor deposition in a mixture of CH@sub 4@ and H@sub 2@ on an electrochemically sharpened tungsten tip. The field emission measurements showed a low turn-on field of ~0.9 V/µm, high emission current of 170 mA and a large field enhancement factor of ~19800. The high field emission current is attributed to the multi stage field enhancement of the two-stage emitter geometry. High emission current of a few µA was also observed in relatively poor vacuum of 3x10 @super -3@ Torr, and the emission properties were recovered at 1x10 @super -6@ Torr after measurements under poor vacuum.

3:20pm **TF1-ThA5 Digital Electrostatic Electron-Beam Array Lithography (DEAL) Prototype Improvements***, **R.B. Rucker**,* University of Tennessee*; S.J. Randolph,* Oak Ridge National Laboratory and University of Tennessee*; L.R. Baylor, W.L. Gardner,* Oak Ridge National Laboratory*; K.L. Klein,* Oak Ridge National Laboratory and University of Tennessee*; M.A. Guillorn,* IBM*; S. Islam, Y. Guan, T. Rahman, S.A. Eliza, T. Grundman, R. Vijayaraghavan,* University of Tennessee*; D.C. Joy, P.D. Rack,* Oak Ridge National Laboratory and University of Tennessee*; D.K. Hensley, R.J. Kasica, D.K. Thomas, T. Bigelow,* Oak Ridge National Laboratory

The Digital Electrostatic electron beam Array Lithography (DEAL) design is presently under development at Oak Ridge National Laboratory.@footnote 1@ The device is designed for massively parallel electron beam lithography that encompasses an array of individually addressable field emitters (FE) and an electrostatic focusing grid. The device design has shifted from utilizing carbon nanofiber (CNF)-based cathodes to tungsten (W) nanofibers deposited by electron-beam-induced deposition (EBID), which has considerably improved the quality and placement of the emitter. The tungsten nanofibers provide performance improvements from the localization of emission sites and a reduction of chromatic aberration. In an effort to increase the depth of focus and lower beam divergence, as well as to function as a focusing electrode, a 500-nm diameter beam- forming aperture has been developed. Fabrication and operation details will be covered, which demonstrates further improved performance of the device design. @FootnoteText@ @footnote 1@This research was sponsored by the Defense Advanced Research Projects Agency (DARPA) under contract No. DARPA-MIPR-97-1357 with ORNL. The research was carried out at ORNL and the University of Tennessee, managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract No. DE-AC05-00OR22725. 2 L. R. Baylor, D. H. Lowndes, M. L. Simpson, C. E. Thomas, M. A. Guillorn, V. I. Merkulov, J. H. Whealton, E. D. Ellis, D. K. Hensley, and A. V. Melechko, J. Vac. Sci. Technol. B 20, 2646 (2002).

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